Groundwater Recharge with Reclaimed Water in California

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In California, increasing demands for water have given rise to surface water development and large-scale projects for water importation. Economic and environmental concerns associated with these projects have expanded interest in reclaiming municipal wastewater to supplement existing water supplies. Groundwater recharge represents a large potential use of reclaimed water in the state. For example, several projects have been identified in the Los Angeles area that could use up to 150 x 10^6 m^3/a (120,000 ac-ft/yr) of reclaimed water for groundwater recharge. Recharging groundwater with reclaimed wastewater has several purposes: to prevent saltwater intrusion into freshwater aquifers, to store the reclaimed water for future use, to control or prevent ground subsidence, and to augment nonpotable or potable groundwater aquifers.[1] Recharge can be accomplished by surface spreading or direct injection.

With surface spreading, reclaimed water percolates from spreading basins through an unsaturated zone to the groundwater. Direct injection entails pumping reclaimed water directly into the groundwater, usually into a confined aquifer. In coastal areas, direct injection effectively creates barriers that prevent saltwater intrusion. In other areas, direct injection may be preferred where groundwater is deep or where the topography or existing land use makes surface spreading impractical or too expensive. While only two large-scale, planned operations for groundwater recharge are using reclaimed water in California, incidental or unplanned recharge is widespread.

The constraints of groundwater recharge with reclaimed water include water quality, the potential for health hazards, economic feasibility, physical limitations, legal restrictions, and the availability of reclaimed water. Of these constraints, the health concerns are by far the most important, as they pervade all potential recharge projects. Health authorities emphasize that indirect potable reuse of reclaimed wastewater through groundwater recharge encompasses a much broader range of potential risks to the public's health than nonpotable uses of reclaimed water. Because the reclaimed water eventually becomes drinking water and is consumed, health effects associated with prolonged exposure to low levels of contaminants and acute health effects from pathogens or toxic substances must be considered. Particular attention must be given to organic and inorganic substances that may elicit adverse health responses in humans after many years of exposure.

HISTORICAL DEVELOPMENT

In the early 1970s several water-quality control plans (Basin Plans) were developed under the direction of the State Water Resources Control Board (SWRCB). The Basin Plans identified as many as 36 potential projects for groundwater recharge in the state. Regulatory agencies involved in wastewater reclamation and reuse play a key role in the management of California's water resources and any projects involving the recharge of groundwater with reclaimed water (see Box). In 1973, the Department of Health Services (DOHS) prepared a position statement in response to proposals in the Basin Plans for augmentation of domestic water sources with reclaimed water. Three uses of reclaimed water were considered in the statement: groundwater recharge by surface spreading, direct injection into an aquifer suitable for use as a domestic water source, and direct discharge of reclaimed water into a domestic water supply.

Position statement. The DOHS position statement recommended against direct discharge into a domestic water-supply system and direct injection into aquifers used as a source of a domestic water supply stating that some organic constituents of wastewater are not well enough understood to permit setting limits and creating treatment-control systems. In particular, the ingestion of water reclaimed from wastewater may produce long-term health effects associated with the stable organic materials that remain after treatment. It also stated that injection to prevent saline water intrusion could be considered in the future. With regard to surface spreading, the position statement contained the following: surface spreading appears to have great potential; information relative to health effects is uncertain; if new information indicates adverse effects are created with recharge, closure of basins may be necessary; specification of allowable percentages of reclaimed water in groundwater is inappropriate at this time because of a lack of information on health effects; proposals for the recharge of small basins with large quantities of reclaimed water will not be

Groundwater recharge, occurring at the Rio Hondo Spreading Grounds in Los Angeles, represents a large potential use of reclaimed water in California.


Sanitation Districts of Los Angeles County

Milestones in Historical Development of Groundwater Recharge

1962 The first large-scale planned operation for groundwater recharge was implemented when secondary effluent from the Whittier Narrows Water Reclamation Plant in Los Angeles County was spread in the Montebello Forebay area of the Central Groundwater Basin.

1973 The California Department of Health Services (DOHS) developed a position statement on the uses of reclaimed water involving ingestion, essentially placing a moratorium on new projects for groundwater recharge.

1975 The State of California convened a Consulting Panel on the Health Aspects of Wastewater Reclamation for Groundwater Recharge to provide recommendations for research that would assist DOHS in the establishment of statewide criteria for groundwater recharge.

1976 DOHS developed draft regulations for groundwater recharge that were subsequently used as guidelines.

1976 Groundwater recharge by direct injection was initiated by the Orange County Water District to prevent saltwater intrusion.

1978 The Sanitation Districts of Los Angeles County (LACSD) initiated a 5-year Health Effects Study to investigate the health significance of using reclaimed water for groundwater replenishment.

1986 The state of California appointed a Scientific Advisory Panel on Groundwater Recharge with Reclaimed Wastewater to provide information needed for the establishment of statewide criteria for groundwater recharge.

1987 State regulatory agencies approved a 50% increase in the amount of reclaimed water that could be spread in the Montebello Forebay area.

Research Tasks

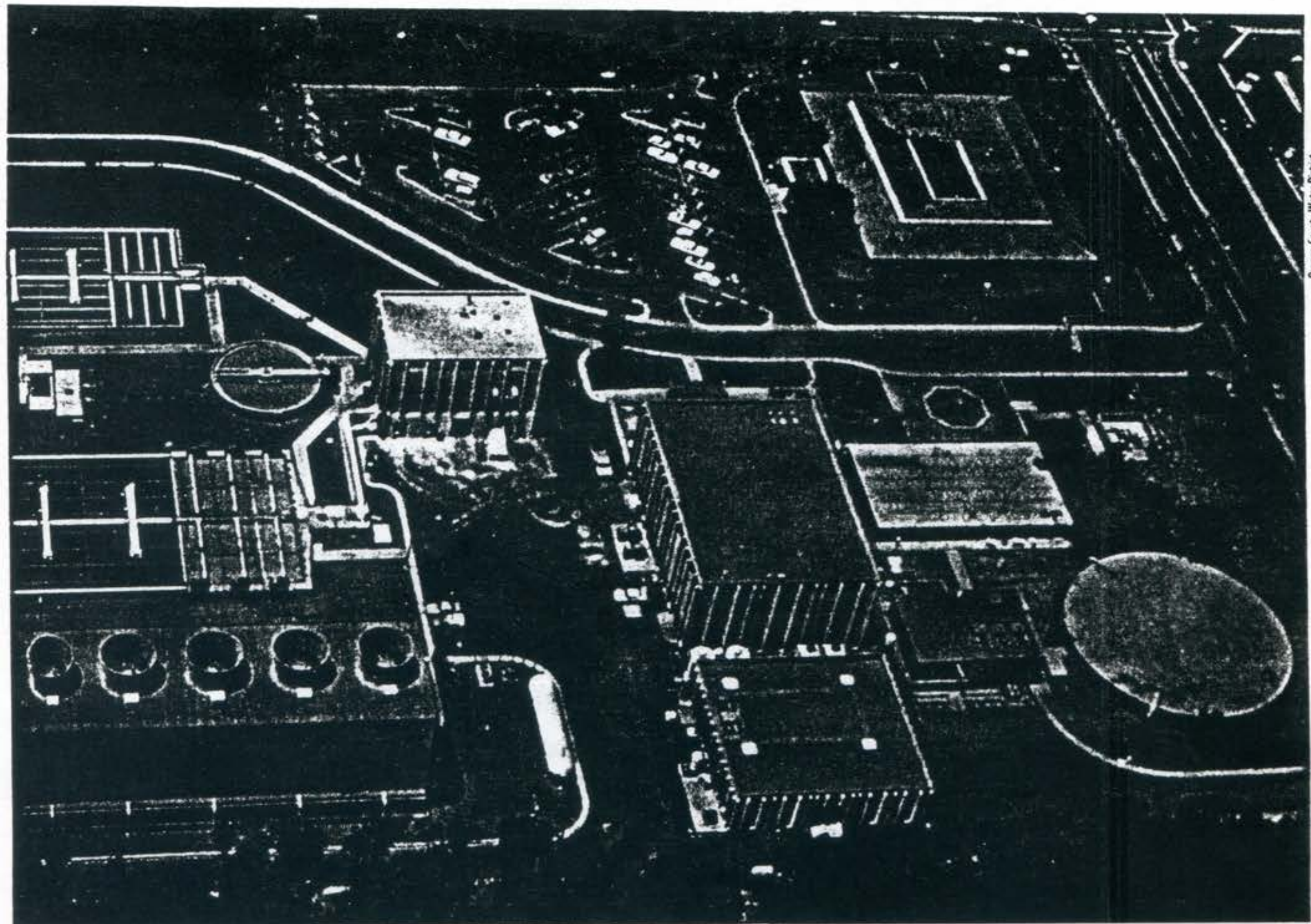
- Water-quality characterizations of groundwater, reclaimed water, and other recharge sources in terms of their microbiological and inorganic chemical content.
- Toxicological and chemical studies of groundwater, reclaimed water, and other recharge sources to isolate and identify health-significant organic constituents.
- Percolation studies to evaluate the efficacy of soil in attenuating inorganic and organic chemicals in reclaimed water.
- Hydrogeological studies to determine the movement of reclaimed water through groundwater and the relative contribution of reclaimed water to municipal water supplies.
- Epidemiological studies of populations ingesting groundwater containing reclaimed water to determine if their health characteristics differ significantly from a demographically similar control population.

recommended; proposals for recharge of large basins with small amounts of reclaimed water may be possible depending on community well locations and other conditions; and surface spreading as a future option may be a possibility.

Consulting panel. In 1975, a Consulting Panel on the Health Aspects of Wastewater Reclamation for Groundwater Recharge was established by three state agencies—DOHS, SWRCB, and the Department of Water Resources (DWR). Its purpose was to recommend a program of research that would provide information to assist DOHS in establishing reclamation criteria for groundwater recharge and to assist DWR and SWRCB in planning and implementing programs to encourage use of reclaimed water consistent with those criteria. A state-of-the-art report on the health aspects of wastewater reclamation for groundwater recharge was prepared as a background document.

The Consulting Panel confined its discussions to groundwater recharge by surface spreading and reached several conclusions. The panel concurred with DOHS that there were uncertainties regarding potential health effects associated with groundwater recharge using reclaimed wastewater. The panel suggested that comprehensive studies directed at the health aspects associated with groundwater recharge be initiated at existing projects, and that new demonstration projects would be needed to gain field information under selected and controlled conditions. The panel stated that to provide a database for estimating health risk, contaminant characterization, toxicology, and epidemiological studies of exposed populations were needed.

Health Effects Study. In the aftermath of the 1976-77 California drought, there was considerable pressure to use supplies of reclaimed water in southern California, particularly for groundwater recharge. However, an unofficial moratorium suspended new projects and the expansion of existing operations until some health-related issues associated with groundwater recharge were answered and the Consult-



Water Factory 21 is an advanced wastewater treatment facility whose effluent is used to prevent saltwater intrusion into potable water-supply aquifers.

ing Panel's recommendations were implemented. In 1978, the Sanitation Districts of Los Angeles County (LACSD) initiated a 5-year, $1.4 million study of the Montebello Forebay Groundwater Recharge Project that had been replenishing groundwater with reclaimed water since 1962. By 1978, the amount of reclaimed water spread averaged 33×10^6 m^3/a (26,500 ac-ft/yr) or 16% of the total inflow to the groundwater basin with no more than 40×10^6 m^3 (32,700 ac-ft) of reclaimed water spread in any year. The percentage of reclaimed water contained in the potable water supply ranged from 0 to 23% on an annual basis, and 0 to 11% on a long-term (1962-1977) basis.

Historical impacts on groundwater quality and human health and the relative impacts of the different replenishment sources—reclaimed water, stormwater runoff, and imported surface water—on groundwater quality were assessed after conducting a wide range of research tasks (see Box).

The study's results indicated that the risks associated with the three sources of recharged water were not significantly different and that the historical proportion of reclaimed water used for replenishment had no measurable impact on either groundwater quality or human health.[2] The Health Effects Study did not demonstrate any measurable adverse effects on the area's groundwater or the health of the population ingesting the water. The cancer-related epidemiological study findings were weakened by the minimal observed latency period (about 15 years) between first exposure and disease for human cancers. Because of the relatively short time that groundwater containing reclaimed water had been consumed, it is unlikely that examination of cancer incidence and mortality rates would have detected an effect of exposure to reclaimed water resulting from this groundwater recharge operation.

Groundwater recharge regulations. In 1976, DOHS developed draft regulations for groundwater recharge of reclaimed water by surface spreading. The proposed criteria were principally directed at the control of stable organics. The level of treatment specified in the draft regulations was conventional secondary treatment followed by carbon adsorption and percolation through at least 3 m (10 ft) of unsaturated soil. Reclaimed water-quality requirements were specified for inorganic chemicals, pesticides, radioactivity, chemical oxygen demand (COD), and total organic carbon (TOC). Requirements for groundwater quality were specified for inorganic chemicals and pesticides. An effluent monitoring program was proposed for 20 specific organic compounds. The draft regulations

Table 1—Analyses of Reclaimed Water—Montebello Forebay, 1988-1989

Constituent	Units	San Jose Creek	Whittier Narrows	Pomona	Discharge limits
Arsenic	mg/L	0.005	0.004	<0.004	0.05
Aluminum	mg/L	<0.06	<0.10	<0.08	1.0
Barium	mg/L	0.06	0.04	0.04	1.0
Cadmium	mg/L	ND	ND	ND	0.01
Chromium	mg/L	<0.02	<0.03	<0.03	0.05
Lead	mg/L	ND	ND	<0.05	0.05
Manganese	mg/L	<0.02	<0.01	<0.01	0.05
Mercury	mg/L	<0.0003	ND	<0.0001	0.002
Selenium	mg/L	<0.001	0.007	<0.004	0.01
Silver	mg/L	<0.005	ND	<0.005	0.05
Lindane	µg/L	0.05	0.07	<0.03	4
Endrin	µg/L	ND	ND	ND	0.2
Toxaphene	µg/L	ND	ND	ND	5
Methoxychlor	µg/L	ND	ND	ND	100
2,4-D	µg/L	ND	ND	ND	100
2,4,5-TP	µg/L	<0.11	ND	ND	10
Suspended solids	mg/L	<3	<2	<1	15
BOD	mg/L	7	4	4	20
Turbidity	TU	1.6	1.6	1.0	2
Total coliform	No./100mL	<1	<1	<1	2.2
Total dissolved solids	mg/L	598	523	552	700
Nitrate and nitrite	mg/L	1.55	2.19	0.69	10
Chloride	mg/L	123	83	121	250
Sulfate	mg/L	108	105	82	250
Fluoride	mg/L	0.57	0.74	0.50	1.6

ND means not detected.

restricted the maximum application of reclaimed water to not more than 50% of the total water spread during a 12-month period. A minimum residence time of 1 year in the underground before groundwater withdrawal was specified. Other proposed requirements included detailed reports on hydrogeology and spreading operations, establishment of a program to control industrial sources, development of contingency plans, and implementation of a program to monitor the health of the population receiving reclaimed water. Because the proposed regulations were based on the worst-case situation and it would have been virtually impossible for any individual project to comply with all of the requirements, the proposed regulations were not adopted as statewide criteria but were used as guidelines for new projects on groundwater recharge.

The DOHS revised the Wastewater Reclamation Criteria in 1978 to require that reclaimed water used for groundwater recharge of aquifers carrying domestic water supplies by surface spreading be of a quality that fully protects public health and that recharge recommendations be based on all relevant aspects of each project. Factors to be considered included treatment provided, effluent quality and quantity, spreading-area operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal. The amendments required that the State Department of Heath Services (DOHS) hold public hearings before projects were approved.

Scientific Advisory Panel. In 1986, California commissioned a Scientific Advisory Panel on Groundwater Recharge with Reclaimed Wastewater that offered several recommendations for statewide water-reuse activities. The Scientific Advisory Panel concurred with the Health Effects Study's findings. The panel advised that the best available water in an area should be reserved for drinking water, the Whittier Narrows Groundwater Replenishment Project should continue, recharge via spreading is preferable to injection, reclaimed water should be disinfected before injection or spreading, and disinfection should not produce harmful by-products. The panel stated that available treatment processes can adequately remove organic constituents of concern, all proposed groundwater recharge projects should include prospective health surveillance of populations, biochemical tests of concentrates are necessary to determine whether likely harmful substances are present at low levels, state-of-the-art toxicology studies with animals are needed for risk evaluation, and there should be continued analytical chemistry investigation and monitoring to identify and quantify chemical constituents.

MAJOR GROUNDWATER-RECHARGE PROJECTS

Two significant projects for groundwater recharge have been implemented in California: one in Montebello Forebay and another in Orange County. Replenishing groundwater basins is accomplished by artificial recharge of aquifers in the Montebello Forebay area of south-central Los Angeles County. Waters used for recharge by surface spreading include local stormwater runoff, imported surface water from the Colorado River and state project, and reclaimed municipal wastewater. The latter has been used as a source of replenishment since 1962, when approximately 15×10^6 m^3/a (12,000 ac-ft/yr) of disinfected activated sludge from the LACSD Whittier Narrows Water Reclamation Plant's (WRP) secondary effluent was spread in the Montebello Forebay that has an estimated usable storage capacity of 960 x 106 m^3 (780,000 ac-ft). In 1973, the San Jose Creek WRP was placed in service and supplied secondary effluent for recharge. In addition, effluent from the Pomona WRP that is not reused for other purposes is discharged into San Jose Creek, a tributary of the San Gabriel River, and ultimately becomes a source for recharge in the Montebello Forebay. The use of effluent from the Pomona WRP is expected to decrease as the reclaimed water is used more for irrigation and industrial applications in the Pomona area.

In 1978, all three reclamation plants were upgraded to provide tertiary treatment with dual-media filtration or filtration with activated carbon and chlorination/dechlorination.[3] The groundwater replenishment program is operated by the Los Angeles County Department of Public Works (DPW), while overall management of the groundwater basin is administered by the Central and West Basin Water Replenishment District. The DPW has constructed special spreading areas designed to increase the indigenous percolation capacity. Specifically, this activity has consisted of modifications to the San Gabriel River channel and construction of off-stream spreading basins adjacent to the Rio Hondo and San Gabriel rivers. The Rio Hondo spreading basins have 173 ha (427 ac) available for spreading and the San Gabriel River spreading grounds have 91 ha (224 ac).

Under normal operating conditions, batteries of basins are rotated through a 21-day cycle. The cycle consists of three 7-day periods during which the basins are filled to maintain a constant depth, the flow to the basins is terminated, and the basins are allowed to drain and dry out thoroughly. This wetting and drying operation serves several purposes, including maintenance of aérobic conditions in the upperstrata of the soil and vector control in the basins.

The reclaimed water produced by each treatment facility complies with primary drinking-water standards and meets total coliform and turbidity requirements of less than 2.2 MPN/ 100 mL and 2 NTU, respectively. Analysis of samples taken at three WRPs from October 1988 through September 1989 provides examples of reclaimed water quality (Tables 1 and 2). The WRPs tested for some constituents in samples taken daily and others in samples taken bimonthly to provide these yearly averages.

In 1987, conceptual authorization was given to increase the amount of reclaimed water used to replenish the Montebello Forebay by approximately 50% over 3 years to allow incremental evaluation, contingent on data generated by an expanded monitoring program. The other general requirements limited the total quantity of reclaimed water spread in any year to 50% of the total inflow to the basin. These requirements, based on an annual running average, stipulated that the reclaimed water must meet all California drinking-water standards and action levels— concentrations of contaminants in drinking water at which adverse health effects would not be anticipated to occur. Approval was also contingent upon demonstrating that there was no measurable increase in organic contaminants in the groundwater caused by the surface spreading of reclaimed water. Since the initial authorization, three incremental increases totaling 21.3×10^6 m^3/a (17,300 ac-ft/yr) have been approved, increasing the quantity of reclaimed water used for groundwater recharge to 62 x 106 m^3/a (50,000 ac-ft/

Table 2—Organic Analyses of Reclaimed Water—Montebello Forebay, 1988-1989

Constituent	Average Concentrations, µg/L			
	San Jose Creek	Whittier Narrows	Ponoma	Discharge limits, µg/L
Atrazine	ND[a]	ND	ND	3
Simazine	ND	ND	ND	10
Methylene chloride	<2.1	8.6	<4.7	40
Chloroform[c]	5.0	4.6	5.5	d
1,1,1-Trichloroethane	<1.0	<1.6	<0.5	200
Carbon tetrachloride	<0.2	<0.3	ND	0.5
1,1-Dichloroethane	<0.2	ND	ND	6
Trichloroethylene	<0.2	ND	<0.3	5
Tetrachloroethylene	<0.8	<0.5	4.1	5
Bromodichloromethane[b]	0.7	<0.6	<0.9	10
Dibromochloromethane[b]	<0 4	<0.3	<0.5	10
Bromoform[b]	<0.3	ND	ND	10
Chlorobenzene	ND	ND	<0.3	30
Vinyl chloride	ND	ND	ND	0.5
o-Dichlorobenzene	<0.7	<0.5	ND	130
m-Dichlorobenzene	ND	ND	ND	130
p-Dichlorobenzene	<1.8	<1.8	ND	5
1,1-Dichloroethane	ND	<0.2	ND	5
1,1,2-Trichloroethane	ND	ND	ND	32
1,2-Dichloroethane	<0.2	<0.3	ND	0.5
Benzene	<0.2	<0.2	ND	1
Toluene	ND	<0.5	ND	100
Ethyl benzene	<0.2	<0.4	<0.3	680
o-Xylene	<0.4	<0.4	<0.4	1750
p-Xylene	<0.4	<0.7	<0.3	1750
Trans-1,2-dichloroethylene	ND	ND	ND	10
1,2-Dichloropropane	ND	ND	ND	5
2 Cis-1,3-Dichloropropene[c]	ND	ND	ND	0.5
Trans-1,3-dichloropropene[c]	ND	ND	ND	0.5
1,1,2,2-Tetrachloroethane	ND	ND	ND	1
Freon 11	ND	ND	ND	150
Pentachlorophenol	ND	ND	ND	30

[a] ND means not detected.
[b] Limit for total trihalomethanes is 100 µg/L.
[c] Limit for total of both isomers is 0.5 µg/L.

Regulatory Authority

The principal agencies involved in wastewater reclamation and reuse in California are the California Department of Health Services (DOHS), local health agencies, the State Water Resources Control Board (SWRCB), and the nine California Regional Water Quality Control Boards (RWQCBs).

The SWRCB and RWQCBs have the primary responsibility for controlling and protecting the water quality in California, and the SWRCB is also responsible for administering water rights. The DOHS has the authority and responsibility to establish health-related standards for wastewater reclamation, including groundwater recharge, and reviews project proposals and individual requirements for wastewater reclamation. If it is determined that contamination exists because of using reclaimed water, DOHS and local health agencies have the authority to order abatement of contamination and issue peremptory orders. Local health agencies can impose requirements more stringent than those specified by DOHS.

The Porter-Cologne Water Quality Control Act gives authority to the nine RWQCBs to establish water-quality standards, to prescribe and enforce requirements for waste discharge to protect surface water and groundwater quality, and, in consultation with DOHS, to prescribe and enforce reclamation requirements. Thus, DOHS's criteria for wastewater reclamation are enforced by the regional boards, and each project must have a permit from the appropriate RWQCB conforming to the DOHS criteria.

Table 3—Water Factory 21 Injection-Water Quality

Constituent	Discharge limits	Injection water
	Concentration in mg/L	
Sodium	115	82
Sulfate	125	56
Chloride	120	84
Total dissolved solids	500	306
Hardness	180	60
pH	6.5-8.5	7.0
Ammonia nitrogen	—	4.7
Nitrate nitrogen	—	0.4
Total nitrogen	10	5.8
Boron	0.5	0.4
Cyanide	0.2	<0.01
Fluoride	1.0	0.5
MBAS	0.5	0.5
	Concentration in μg/L	
Arsenic	50	<5.0
Barium	1000	18
Cadmium	10	0.6
Chromium	50	<1.0
Cobalt	200	<1.0
Copper	1000	4.7
Iron	300	33
Lead	50	<1.0
Manganese	50	4.3
Mercury	2	<0.5
Selenium	10	<5.0
Silver	50	3.3

yr), or approximately 30% of the total inflow to the Montebello Forebay. This level of reuse represents a significant effort in water conservation corresponding to the replacement of potable water that would otherwise be used by about 50,000 households.

Additional research since the completion of the Health Effects Study conducted by LACSD included an evaluation of the efficiency of LACSD's full-scale carbon filters for removing mutagenicity as determined by the *Salmonella* microsome assay.[4] Results from this work indicate that average mutagenicity removals of 80% could be achieved based on a 10-minute, empty-bed contact time, and that the effects of chlorine disinfection on mutagenic activity vary significantly. These later results suggest that chlorine can oxidize and thus deactivate some types of mutagens, but also can react with available organic matter to create more mutagens in a given sample.

Ongoing research has focused on the development of a groundwater tracer suitable for characterizing the movement of reclaimed water in groundwater basins. The study has thus far evaluated a series of alkyl pyridone sulfonate (APS) compounds and several fluorocarbon compounds in the laboratory to measure the degree of adsorption of these compounds on soils and their ability to withstand photodecomposition and biodegradation under aerobic and anaerobic conditions. Volatility studies and biological assays have been conducted to determine the potential of the tracer compounds to elicit acute toxicity or mutagenicity. The laboratory phase of study has been completed and the second phase of study will consist of investigations to verify the laboratory results under actual field conditions.

Additional research has been proposed to provide comparative, supplemental data for the Health Effects Study's findings. Plans call for similar toxicological and chemical procedures to be used to characterize any changes in reclaimed water or groundwater quality that might have occurred since the study's samples were originally collected for evaluation. Additionally, the proposed work would attempt to use current techniques to learn more about the characteristics of compounds in mutagenic fractions, thereby providing a better understanding of the origins and health significance of these compounds and the alternatives available for their removal.

Water Factory 21 direct injection project. A project involving groundwater recharge by the injection of reclaimed water is operated by the Orange County Water District (OCWD). The OCWD first began pilot studies in 1965 to determine the feasibility of using effluent from an advanced wastewater treatment (AWT) facility in a hydraulic barrier to prevent the encroachment of saltwater into aquifers carrying potable water supplies. Construction of an AWT facility known as Water Factory 21 was started in 1972 in Fountain Valley, and injection operations began in 1976.

Water Factory 21 has a design capacity of 0.7 m^3/s (15 mgd) and can treat the secondary effluent's activated sludge from the adjacent Orange County Sanitation District's (OCSD) Sewage Treatment Plant by the following unit operations: lime clarification for removal of suspended solids, heavy metals, and dissolved minerals; air stripping (not currently in service) for removal of ammonia and volatile organic compounds; carbonation for pH control, mixed-media filtration for removal of suspended solids, adsorption with activated carbon for removal of dissolved organics; reverse osmosis (RO) for demineralization; and chlorination for biological control and disinfection. Because of a required 500-mg/L limitation of total dissolved solids before injection, RO is used to demineralize up to 0.2 m^3/s (5 mgd) of the wastewater used for injection.

The feed water to the RO plant is effluent from the mixed-media filters. Effluent from carbon columns is disinfected and blended with RO-treated water. Activated carbon is regenerated on site. Solids from the settling basins are incinerated in a multiple-hearth furnace from which lime is recovered and reused in the chemical clarifier. Brine from the RO plant is pumped to OCSD's facilities for ocean disposal.

Reclaimed water produced at Water Factory 21 is injected into a series of 23 multi-casing wells providing 81 individual injection points into four aquifers to form a seawater-intrusion barrier known as the Talbert Injection Barrier. The injection wells are located approximately 5.6 km (3.5 miles) inland from the Pacific Ocean. There are seven extraction wells not currently being used located between the injection wells and coast. Before injection, the product water is blended 2:1 with deep-well water from an aquifer not subject to contamination. Depending on basin conditions, the injected water flows toward the ocean forming a seawater barrier, flows inland to augment the potable groundwater supply, or both.

The AWT processes at Water Factory 21 reliably produce high-quality water. No coliform organisms were detected in any of the 179 samples of Water

Factory 21 effluent tested during 1988. Although the discharge permit requires OCWD to institute a virus monitoring program that is acceptable to DOHS, virus sampling is not being conducted at present. A virus monitoring program conducted from 1975 to 1982 demonstrated to the satisfaction of the state and county health agencies that Water Factory 21 produces effluent that is essentially free of measurable levels of viruses. The average turbidity of filter effluent was 0.22 FTU and did not exceed 1.0 FTU during 1988. The average COD and TOC concentrations for the year were 8 mg/L and 2.6 mg/L, respectively. The effectiveness of Water Factory 21's treatment processes for the removal of inorganic and organic constituents is shown in the present water-quality data for the blended injection water (Tables 3 and 4). Fifty-three specific volatile organic compounds were not detected in injection water samples, which were blended in a 2:1 ratio with deep-well water before analysis.

The OCWD has developed a plan for groundwater management in response to potential water shortages and local water-quality problems. The plan documents several potential projects to reuse wastewater by groundwater recharge. Included is the possible expansion of Water Factory 21 to provide injection water for seawater-intrusion barriers at Sunset and Bolsa Gaps in Orange County, and for injecting reclaimed water directly into the groundwater basin in central Orange County. Another project under consideration is the construction of an AWT facility, similar to Water Factory 21, that would provide reclaimed water for a seawater-intrusion barrier at Alamitos Gap. Based on current growth projections, wastewater treatment capacity in the service area of OCSD will be exceeded by the year 2000. A possible project involves construction of a wastewater reclamation plant in the Anaheim area, where as much as 1.1 m^3/s (25 mgd) of reclaimed water could be used for various types of reuse, including groundwater recharge by direct injection.

Table 4—Volatile Organic Compounds in Injection Water—Water Factory 21

Constituent	Injection water µg/L
Methylene chloride	1.0
Chloroform	5.4
Dibromochloromethane	1.1
Chlorobenzene	Trace amount
Bromodichloromethane	3.7
Bromoform	0.8
1,1,1-Trichloroethane	Trace amount

The Goals and Objectives of the Guidelines for Groundwater Recharge with Reclaimed Municipal Wastewater

- To plan and encourage efficient use of the state's water resources and increase the reliability of the water supply by implementing the safe use of treated municipal wastewater for groundwater recharge
- To guide the RWQCBs in establishing objectives for groundwater quality and requirements for wastewater reclamation that will adequately protect health and environment while encouraging optimum use of the region's water resources
- To ensure that groundwater recharge with reclaimed wastewater, whether planned or incidental, is regulated in a consistent manner
- To assist planning for groundwater recharge with reclaimed wastewater by providing the criteria and guidelines that detail the required information for review by regulatory agencies

GUIDELINES FOR GROUNDWATER RECHARGE

Groundwater recharge with reclaimed water represents a large potential use of reclaimed water in California; yet there are few planned recharge projects in the state, partly because of economic considerations and continuing health concerns. This situation, coupled with the knowledge that unplanned or incidental recharge with wastewater is widespread and relatively uncontrolled, suggested that it was essential to undertake a comprehensive review of existing regulations and establish statewide policies and guidelines for planning and implementing new projects for groundwater recharge. In a coordinated effort to address these needs, DOHS, SWRCB, and DWR are developing a document titled "Guidelines for Groundwater Recharge with Reclaimed Municipal Wastewater." It is anticipated that the guidelines will be adopted by the DOHS in 1991 (see Box).

The proposed guidelines include principles, permitting procedures, and criteria for groundwater recharge. The criteria for surface spreading and injection of reclaimed water will address treatment processes, treatment reliability, water quality, monitoring, dilution, time underground, distance to withdrawal, and operational procedures. It is anticipated that criteria for groundwater recharge will be somewhat flexible and take into consideration site-specific conditions such as percolation rate and depth to groundwater. The criteria are currently under development by DOHS, with input from other state and local regulatory agencies, and operating agencies. The guidelines will also include a background document to provide a detailed rationale for the criteria. ■

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